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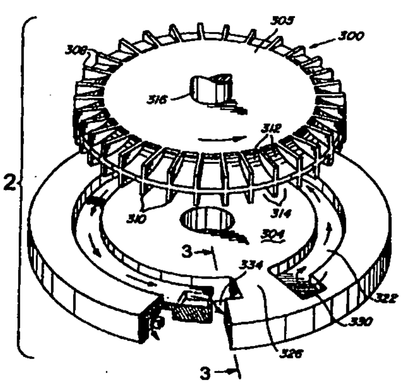
(54) Turbomolecular vacuum pumps

(57) In order to provide increased pumping speed, increased discharge pressure and decreased operating power in comparison with prior art turbomolecular vacuum pumps there is proposed that one or more stages of the vacuum pump are regenerative stages, each including a regenerative impeller, wherein pumping channels (322) in the upper and lower portions of the stator (304) are connected in series. The stator channels (322) can be provided with fixed, spaced-apart ribs for improved performance.

FIG. 2



EP 0 770 781 A1

Description

Field of the Invention

This invention relates to turbomolecular vacuum pumps according to the preamble of claim 1 and 11, respectively and, more particularly, to turbomolecular vacuum pumps having structures which provide increased pumping speed, increased discharge pressure and decreased operating power in comparison with prior art turbomolecular vacuum pumps.

Background of the Invention

Conventional turbomolecular vacuum pumps include a housing having an inlet port, an interior chamber containing a plurality of axial pumping stages and an exhaust port. The exhaust port is typically attached to a roughing vacuum pump. Each axial pumping stage includes a stator having inclined blades and a rotor having inclined blades. The rotor and stator blades are inclined in opposite directions. The rotor blades are rotated at high speed to provide pumping of gases between the inlet port and the exhaust port. A typical turbomolecular vacuum pump includes nine to twelve axial pumping stages, preferably arranged in two or three stages for low pressure, medium pressure and high pressure as taught by US-A-3,644,051 (corresponding to DE-A-2 046 693) and DE-U-7 237 362. However the arrangement of several rotor / stator units in a working group having the same configuration creates a discontinuous fluid flow from one stage to the following resulting in low compression ratios.

Variations of the conventional turbomolecular vacuum pump are known in the prior art. In one prior art vacuum pump, a cylinder having helical grooves, which operates as a molecular drag stage, is added near the exhaust port. In another prior art configuration, one or more of the axial pumping stages are replaced with disks that rotate at high speed and function as molecular drag stages. A disk which has radial ribs at its outer periphery and which functions as a regenerative centrifugal impeller is disclosed in the prior art.

Turbomolecular vacuum pumps utilizing molecular drag disks and regenerative impellers are disclosed in DE-A-3,919,529 (published January 18, 1990). Corresponding US-Patent No. 5,074,747 discloses a vacuum pump having a peripheral groove vacuum pump unit which includes a casing provided with an inlet port and an outlet port; a rotor disposed within the casing and including a rotor shaft journaled on the casing, a rotor body fixed to the rotor shaft and provided integrally with a rotor disk; and a stator fixedly disposed within the casing and provided with an annular groove receiving the peripheral portion of the rotor disk. Both sides of the peripheral portion of the rotor disk are cut in steps or portions of the side walls of the annular groove corresponding to the peripheral portion of the rotor disk are cut in annular recesses to form flow passages on both sides of the peripheral portion of the rotor disk. Partitions are projected from the stator into the flow passages. The starting ends of the flow passages on the inlet side of the partitions communicate with the inlet port, and the terminating ends of the same on the outlet side of the partitions communicate with the outlet port.

While prior art turbomolecular vacuum pumps have generally satisfactory performance under a variety of conditions, it is desirable to provide turbomolecular vacuum pumps having improved performance. In particular, it is desirable to increase the compression ratio so that such pumps can discharge to atmospheric pressure or to a pressure near atmospheric pressure. In addition, it is desirable to provide turbomolecular vacuum pumps having increased pumping speed and decreased operating power in comparison with prior art pumps.

It is a general object of the present invention to provide improved turbomolecular vacuum pumps.

It is another object of the present invention to provide turbomolecular vacuum pumps capable of discharging to relatively high pressure levels.

It is another object of the present invention to provide turbomolecular vacuum pumps having relatively high pumping speeds.

It is a further object of the present invention to provide turbomolecular vacuum pumps having relatively low operating power.

It is a further object of the present invention to provide turbomolecular vacuum pumps having high compression ratios for light gases.

It is still another object of the present invention to provide turbomolecular vacuum pumps which are easy to manufacture and which are relatively low in cost.

Summary of the Invention

These and other objects and advantages are achieved in accordance with the present invention by a turbomolecular vacuum pump according to claim 1 and 11, respectively.

Accordingly, a turbomolecular vacuum pump comprises a housing having an inlet port and an exhaust port, a plurality of vacuum pumping stages located within the housing and disposed between the inlet port and the exhaust port, each of the vacuum pumping stages including a rotor and a stator, and means for rotating the rotor such that gas is pumped from the inlet port to the exhaust port. One or more of the vacuum pumping stages of the turbomolecular vacuum pump comprise a regenerative stage including a rotor and a stator. The rotor comprises a disk. First spaced-apart rotor ribs are formed in an upper surface of the disk, and second spaced-apart rotor ribs are formed in a lower surface of the disk. The disk constitutes a regenerative impeller. The stator defines a first annular channel in opposed relationship to the first rotor ribs, a second annular channel in opposed relationship to the second rotor ribs and a conduit connecting the first and second annular channels. The stator of the regenerative stage

further includes a blockage in each of the first and second annular channels so that gas flows in series through the first annular channel and the second annular channel.

In a preferred embodiment of the regenerative stage, the first and second channels are spaced inwardly from an outer peripheral edge of the disk so that the outer peripheral edge of the disk extends into the stator, and leakage between the first and second channels is limited.

According to a further embodiment of the invention, third spaced-apart rotor ribs formed in the upper surface of the disk, and fourth spaced-apart rotor ribs are formed in the lower surface of the disk. The stator includes third and fourth annular channels in opposed relationship to the third and fourth rotor ribs, respectively. The third annular channel is connected by a conduit to the first annular channel, and the fourth annular channel is connected by a conduit to the second annular channel. Gas flows through the first, second, third and fourth annular channels in series.

According to yet another feature of the invention, the stator channels of the regenerative stage are provided with spaced-apart stator ribs. The stator ribs can lie in radial planes or can be inclined.

Brief Description of the Drawings

For better understanding of the present invention, together with other and further objects, advantages and capabilities thereof, reference is made to the accompanying drawings which are incorporated herein by reference and in which:

Fig. 1 is a partially broken away, perspective view of a turbomolecular vacuum pump showing the general structure thereof;

Fig. 2 is an exploded perspective view of a regenerative vacuum pumping stage showing a regenerative impeller and a lower stator portion in accordance with the invention;

Fig. 3 is a partial cross-sectional view of the vacuum pumping stage of Fig. 2;

Fig. 4 is a partial cross-sectional plan view of the vacuum pumping stage taken along the line 4-4 of Fig. 3;

Fig. 5 is a partial cross-sectional view of another embodiment of the vacuum pumping stage of Fig. 2;

Fig. 6 is a partial cross-sectional elevation view of the regenerative vacuum pumping stage taken along the line 6-6 of Fig. 5 and showing gas flow through the upper and lower pumping channels;

Fig. 7 is a partial cross-sectional view of another embodiment of the vacuum pumping stage of Fig. 2 wherein the stator channels are provided with ribs;

Fig. 8 is a partial cross-sectional elevation view of the vacuum pumping stage taken along the line 8-8 of Fig. 7;

Fig. 9 is an alternate embodiment of the vacuum pumping stage of Figs. 7 and 8 wherein the rotor and stator ribs are inclined;

Fig. 10 is an exploded perspective view of a regenerative vacuum pumping stage, showing a regenerative impeller and a lower stator portion in accordance with another embodiment of the invention;

Fig. 11 is a partial cross-sectional view of the regenerative vacuum pumping stage of Fig. 10;

Fig. 12 is an exploded perspective view of a regenerative vacuum pumping stage wherein the rotor and stator ribs are inclined with respect to the direction of rotor motion to reduce noise during operation;

Fig. 13 is a graph showing compression ratio, pumping speed and input power of the turbomolecular vacuum pump of the present invention for each vacuum pumping stage; and

Fig. 14 is a graph of throughput of the turbomolecular vacuum pump of the present invention as a function of inlet pressure.

Detailed Description of the Invention

An exemplary turbomolecular vacuum pump in accordance with the "parent" application EP 93 106 976.9 is shown in Fig. 1 to illustrate the general structure thereof. A housing 10 defines an interior chamber 12 having an inlet port 14 and an exhaust port 16. The housing 10 includes a vacuum flange 18 for sealing of inlet port 14 to a vacuum chamber (not shown) to be evacuated. Located within chamber 12 is a plurality of axial flow vacuum pumping stages. Each of the vacuum pumping stages includes a rotor 20 and a stator 22. The turbomolecular vacuum pump of Fig. 1 includes eight stages. It will be understood that a different number of stages can be utilized depending on the vacuum pumping requirements. Typically, turbomolecular vacuum pumps have about nine to twelve stages.

Each rotor 20 includes a central hub 24 attached to a shaft 26. Inclined blades 28 extend outwardly from the hub 24 around its periphery. Typically, all of the rotors have the same number of inclined blades, although the angle and width of the inclined blades may vary from stage to stage.

The shaft 26 is rotated at high speed by a motor located in a housing 27 in a direction indicated by arrow 29 in Fig. 1. The gas molecules are directed generally axially by each vacuum pumping stage from the inlet port 14 to the exhaust port 16.

The stators can have different structures in different stages. Specifically, one or more stators in proximity to inlet port 14 have a conventional structure with relatively high conductance. In the turbomolecular vacuum pump of Fig. 1, two stages in proximity to inlet port 14 have stators with relatively high conductance. The high conductance stators 22 include inclined blades 30 which extend inwardly from a circular spacer to a hub. The hub has an opening for a shaft 26 but does not contact shaft 26. In the first two stages of the vacuum pump in proximity to inlet port 14, the stators 22 usually have the same number of inclined blades as the rotor 20. The blades of the rotor and the blades of the stator are inclined in opposite directions.

A first aspect of the present invention is shown in Figs. 2-4. One or more axial flow vacuum pumping stages of a conventional turbomolecular vacuum pump are replaced with regenerative vacuum pumping stages. A regenerative vacuum pumping stage includes a regenerative impeller 300 which operates with a stator having an upper stator portion 302 adjacent to an upper surface of the regenerative impeller 300, and a lower stator portion 304 adjacent to the lower surface of the regenerative impeller 300. The upper stator portion 302 is omitted from Fig. 2 for clarity. The regenerative impeller 300 comprises a disk 305 having spaced-apart radial ribs 308 on its upper surface and spaced-apart radial ribs 310 on its lower surface. The ribs 308 and 310 are preferably located at or near the outer periphery of disk 305. Cavities 312 are defined between each pair of ribs 308, and cavities 314 are defined between each pair of ribs 310. In the embodiment shown in Figs. 2-4, the cavities 312 and 314 have curved contours formed by removing material of the disk 305 between ribs 308 and between ribs 310. The cross-sectional shape of the cavities 312 and 314 can be rectangular, triangular, or any other suitable shape. The disk 305 is attached to a shaft 316 (corresponding to shaft 26 of Fig.1) for high speed rotation around a central axis.

The upper stator portion 302 has a circular upper channel 320 formed in opposed relationship to ribs 308 and cavities 312. The lower stator portion 304 has a circular lower channel 322 formed in opposed relationship to ribs 310 and cavities 314. The upper stator portion 302 further includes a blockage (not shown) of channel 320 in one circumferential location. The lower stator portion 304 includes a blockage 326 of channel 322 at one circumferential location. The stator portions 302 and 304 define a conduit 330 adjacent to blockage 326 that interconnects upper channel 320 and lower channel 322 around the edge of disk 305. Upper channel 320 receives gas from a previous stage through a conduit (not shown). The lower channel 322 discharges gas to a next stage through a conduit 334.

In operation, disk 305 is rotated at high speed about shaft 316. Gas entering upper channel 320 from the previous stage is pumped through upper channel 320. The rotation of disk 305 and ribs 308 causes the gas to be pumped along a roughly helical path through cavities 312 and upper channel 320, as best shown in Figs. 3 and 6. The gas then passes through conduit 330 into lower channel 322 and is pumped through channel 322 by the rotation of disk 305 and ribs 310. In the same manner, the ribs 310 cause the gas to be pumped in a roughly helical path through cavities 314 and lower channel 322. The gas is then discharged to the next stage through conduit 334.

It will be understood that the shape, size and spacing of ribs 308 and 310 and the size and shape of the corresponding cavities 312 and 314 can be varied within the scope of the present invention. The principal requirement is for a regenerative impeller having ribs on its upper and lower surfaces, and corresponding pumping channels in the stator which are connected so that gas is pumped in series through the upper stator channel and the lower stator channel to provide a high compression ratio.

Another feature of the regenerative vacuum pumping stage is illustrated in Fig. 5. Like elements in Figs. 3 and 5 have the same reference numerals. The disk 305 is preferably provided with an extended lip 340 at its outer periphery. The lip 340 extends radially outwardly from ribs 308 and 310 into a groove 342 in stator portions 302 and 304. As in the case of the molecular drag stages described above, the lip 340 and the groove 342 limit leakage between upper channel 320 and lower channel 322 by providing a relatively long leakage path between these channels. As in the case of the molecular drag stage, it is desirable to position ribs 308 and 310 and corresponding channels 320 and 322 as near as possible to the outer periphery of disk 300, while minimizing leakage between upper channel 320 and lower channel 322.

Another embodiment of the regenerative vacuum pumping stage of Figs. 2-4 is shown in Figs. 7 and 8. Like elements in Figs. 2-4, 7 and 8 have the same reference numerals. The regenerative impeller 300 shown in Fig. 7 has the same construction as shown in Fig. 2, including disk 305 with ribs 308 and 310. The upper channel 320 in stator portion 302 is provided with fixed, spaced-apart radial stator ribs 350. Similarly, the lower channel 322 in stator portion 304 is provided with fixed, spaced-apart radial stator ribs 352. Cavities 354 are defined between ribs 350, and cavities 356 are defined between ribs 352. The stator ribs 350 and 352 reduce reverse flow through channels 320 and 322, respectively.

Another embodiment of the regenerative vacuum pumping stage of Figs. 7 and 8 is shown in Fig. 9. A regenerative impeller disk 360 is provided with ribs 362 on an upper surface near the outer periphery thereof and ribs 364 on a lower surface near the outer periphery thereof. The ribs 362 and 364 are inclined with respect

to radial planes. An upper stator portion 366 defines an upper channel 368 in opposed relationship to ribs 362. Fixed, spaced-apart ribs 370 are located in upper channel 368. A lower stator portion 372 defines a lower channel 374 in opposed relationship to ribs 364. Fixed, spaced-apart ribs 376 are located in lower channel 374. The ribs 370 and 376 are inclined with respect to radial planes. Ribs 370 are inclined in an opposite direction with respect to ribs 362. Ribs 376 are inclined in an opposite direction with respect to ribs 364. The configuration of ribs shown in Fig. 9 provides the advantages described above. The stator ribs shown in Figs. 7 to 9 can be used in a configuration wherein the upper and lower channels are connected in series.

Alternatively, the stator ribs can be utilized in a configuration wherein the upper and lower channels are connected in parallel.

Another embodiment of the regenerative vacuum pumping stage is shown in Figs. 10 and 11. The regenerative stage includes a regenerative impeller 400, an upper stator portion 402 adjacent to an upper surface of impeller 400 and a lower stator portion 404 adjacent to a lower surface of impeller 400. The regenerative impeller 400 includes a disk 405 having spaced-apart radial ribs 408 in a circular pattern at or near the outer periphery of disk 405 and spaced-apart radial ribs 406 in a circular pattern spaced inwardly from ribs 408. Similarly, the lower surface of disk 405 is provided with spaced-apart radial ribs 410 at or near the outer periphery of disk 405 and spaced-apart radial ribs 412 in a circular pattern spaced inwardly from ribs 410. The disk 405 is provided with an outer peripheral lip 414 to reduce leakage between the upper and lower surfaces of disk 405.

The upper stator portion 402 defines a circular pumping channel 418 in opposed relationship to ribs 406 and a circular pumping channel 420 in opposed relationship to ribs 408. The lower stator portion 404 defines a circular pumping channel 422 in opposed relationship to ribs 410 and a circular pumping channel 424 and opposed relationship to ribs 412. The upper stator portion 402 includes blockages (not shown) in channels 418 and 420, respectively. Similarly, lower stator portion 404 includes blockages 430 and 432 in pumping channels 422 and 424, respectively. The pumping channel 422 is provided with spaced-apart, radial stator ribs 423, and the pumping channel 424 is provided with spaced-apart, radial stator ribs 425. The pumping channels 418 and 420 in upper stator portion 402 have similar spaced-apart, radial stator ribs. The stator ribs in the pumping channels reduce reverse leakage. The outer peripheral lip 414 of disk 405 extends into a circular groove 426 in upper stator portion 402 to reduce leakage between the upper and lower surfaces of disk 405.

A conduit 434 through upper stator portion 402 provides inlet to channel 418 from a previous stage. A conduit 436 through upper stator portion 402 interconnects channels 418 and 420. A conduit 440 through stator portions 402 and 404 interconnects channels 420 and 422 around the outer peripheral edge of disk 405. A conduit 442 through lower stator portion 404 interconnects channels 422 and 424. A conduit 444 through lower stator portion 404 interconnects the regenerative stage to the next vacuum pumping stage or to the exhaust port of the vacuum pump.

In operation, gas enters the regenerative vacuum pumping stage through conduit 434 from the previous stage and is pumped through circular channel 418 to conduit 436. The gas is then pumped through circular channel 420 and conduit 440 to channel 422 on the lower surface of disk 405. After the gas is pumped through circular channel 422, it passes through conduit 442 and is pumped through circular channel 424. Finally, the gas is exhausted through conduit 444 to the next stage. The regenerative vacuum pumping stage shown in Fig. 11 provides serial vacuum pumping through four pumping channels in series. Each channel has a regenerative configuration using a single regenerative impeller 400. As a result, the regenerative stage of Fig. 11 provides a high compression ratio.

The ribs in the rotor and the stator of the regenerative stage of Figs. 10 and 11 can be varied as to size (height) and shape within the scope of the present invention. It will be understood that a different number of pumping channels can be utilized. For example, one of the pumping channels shown in Figs. 10 and 11 can be omitted to provide a three channel regenerative stage, or more than four pumping channels can be utilized. The principal requirement is that the pumping channels be connected in series for a relatively high compression ratio.

Another embodiment of the regenerative vacuum pumping stage is shown in Fig. 12. The embodiment of Fig. 12 is similar to the embodiment of Figs. 7 and 8, except that the rotor ribs and the stator ribs are inclined with respect to the direction of rotor rotation for smoother pumping action and to reduce noise. A regenerative impeller 500 operates with a rotor including an upper stator portion (not shown) adjacent to an upper surface of the regenerative impeller 500 and a lower stator portion 504 adjacent to a lower surface of the regenerative impeller 500. The upper stator portion is omitted from Fig. 12 for clarity. The regenerative impeller 500 comprises a disk 505 having spaced-apart rotor ribs 508 on its upper surface, and spaced-apart rotor ribs 510 (shown in phantom in Fig. 12) on its lower surface. The rotor ribs 508 and 510 are preferably located at or near the outer periphery of disk 505. Cavities 512 are defined between each pair of rotor ribs 508, and cavities (not shown) are defined between each pair of rotor ribs 510. The cavities between ribs 508 and 510 can have any suitable shape. The disk 505 is attached to a shaft 516 for high speed rotation around a central axis.

The lower stator portion 504 has a circular lower channel 522 formed in opposed relationship to ribs 510 and the corresponding cavities between ribs 510. The lower stator portion 504 further includes a blockage 524 of channel 522 at one circumferential location. The

lower channel 522 is provided with spaced-apart stator ribs 526 which define cavities 528 between them. The upper stator portion has a construction similar to that of lower stator portion 504. A conduit 530 adjacent to blockage 524 interconnects the channel in the upper stator portion and lower channel 522 around the edge of disk 505. The lower channel 522 discharges gas to a next stage through a conduit 532.

The rotor ribs 508 and 510 are inclined with respect to the direction of rotation of disk 505. Similarly, the stator ribs 526 in lower channel 522 and the stator ribs in the channel of the upper stator portion are inclined with respect to the direction of rotation of disk 505. However, the ribs in the stator are inclined in the opposite direction with respect to the ribs in the rotor so that the opposed rotor and stator ribs intersect to form X's as shown in Fig. 12. The inclined ribs in the rotor and stator channels reduce a momentary interruption of pumping (when the ribs are aligned) and the generation of noise during operation. The embodiment of Fig. 12 otherwise operates in a manner similar to the regenerative vacuum pumping stages described above and shown in the "parent" application EP 93 106 976.9.

The operating characteristics of turbomolecular vacuum pumps in accordance with the present invention are illustrated in Figs. 13 and 14. In Fig. 13, the pumping speed, compression ratio and input power of each stage in a multistage pump are plotted. The different stages of the pump are plotted on the horizontal axis, with high vacuum stages at the left and low vacuum stages at the right. Curve 550 represents the compression ratio and indicates that a low compression ratio is desired near the inlet port of the pump. The compression ratio reaches a maximum near the middle of the pump and decreases near the exhaust port. In general, a high compression ratio is easy to achieve in molecular flow but is difficult to achieve in viscous flow. Near the pump inlet port, the compression ratio is intentionally made low in order to obtain high pumping speed. After the gas being pumped has been densified, a higher compression ratio and a lower pumping speed are desired. The pumping speed is indicated by curve 552. A relatively high compression ratio is obtained at the higher pressures near the pump outlet by minimizing leakage, using the techniques described above, and by increasing the pump power. High pumping speed is not required near the exhaust port because the gas is densified in this region. The pump input power is indicated by curve 554. At low pressures, required power is required mainly to overcome bearing friction. At higher pressure levels, gas friction and compression power add to the power consumed by the pump. In general, the operating point of each stage is individually selected in accordance with the present invention.

In Fig. 14, the throughput of the turbomolecular vacuum pump is plotted as a function of inlet pressure. The throughput is indicated by curve 560. The point at which the throughput becomes constant is selected as a function of maximum design mass flow and maximum design power.

Claims

1. A turbomolecular vacuum pump comprising:

   a housing having an inlet port and an exhaust port;
   a plurality of vacuum pumping stages located within said housing and disposed between said inlet port and said exhaust port, each of said vacuum pumping stages including a rotor (300) and a stator (302); and
   means for rotating said rotors (300) such that gas is pumped from said inlet port to said exhaust port; characterized by one or more of said vacuum pumping stages comprising a regenerative stage including a rotor (300) comprising a disk (305) having first, spaced-apart rotor ribs (308) formed in an upper surface and second, spaced-apart rotor ribs (310) formed in a lower surface, said disk (305) constituting a regenerative impeller, said regenerative stage further including a stator that defines a first annular channel (320) in opposed relationship to said first rotor ribs (308), a second annular channel (322) in opposed relationship to said second rotor ribs (310), and a conduit (330) between said first and second annular channels (320, 322), the stator of said regenerative stage further including a blockage (326) in each of said first and second annular channels (320, 322) so that gas flows in series through said first annular channel (320) and said second annular channel (322).

2. A turbomolecular vacuum pump as defined in claim 1 wherein said first rotor ribs (308) and second rotor ribs (310) lie in radial planes.

3. A turbomolecular vacuum pump as defined in claim 1 or 2 wherein said first and second channels (320, 322) are spaced inwardly from an outer peripheral edge (340) of said disk (305) so that the outer peripheral edge (340) of said disk (350) extends into said stator (302) and leakage between said first and second channels (320, 322) is limited.

4. A turbomolecular vacuum pump as defined in any of claims 1 to 3 wherein said disk (405) further includes third, spaced-apart rotor ribs (406) formed in said upper surface, and the stator (402) of said regenerative stage defines a third annular channel (418) in opposed relationship to said third rotor ribs (406), a blockage in said third annular channel (418) and a conduit (436) between said first and third annular channels (418, 420) so that gas flows in series through said first and third annular channels.

5. A turbomolecular vacuum pump as defined in claim 4 wherein said disk (405) further includes fourth, spaced-apart rotor ribs (412) formed in said lower surface, and the stator (404) of said regenerative stage defines a fourth annular channel (424) in opposed relationship to said fourth rotor ribs (412), a blockage in said fourth annular channel and a conduit (442) between said second and fourth annular channels (422, 424) so that gas flows in series through said second and fourth annular channels.

6. A turbomolecular vacuum pump as defined any of claims 1 to 5 wherein said first channel and said second channel are each provided with spaced-apart stator ribs (350, 352; 370, 376).

7. A turbomolecular vacuum pump as defined in claim 6 wherein the stator ribs (350, 352) in said first and second channels lie in radial planes.

8. A turbomolecular vacuum pump as defined in claim 6 wherein said rotor ribs (362) are inclined with respect to the direction of rotation of said rotor (360) and said stator ribs (370, 376) are inclined with respect to the direction of rotation of said rotor (360), said rotor ribs and said stator ribs being inclined in opposite directions.

9. A turbomolecular vacuum pump as defined in any of claims 4 to 8 wherein said first, second and third channels are each provided with spaced-apart stator ribs.

10. A turbomolecular vacuum pump as defined in any of claims 5 to 8 wherein said first, second, third and fourth channels are each provided with spaced-apart stator ribs.

11. A turbomolecular vacuum pump comprising:

a housing having an inlet port and an exhaust port;
a plurality of vacuum pumping stages located within said housing and disposed between said inlet port and said exhaust port, each of said vacuum pumping stages including a rotor (500) and a stator (504); and
means for rotating said rotors (500) such that gas is pumped from said inlet port to said exhaust port; characterized by one or more of said vacuum pumping stages comprising a regenerative stage including a rotor (500), comprising a disk (505) having spaced-apart rotor ribs (508, 510) formed on at least one surface at or near an outer periphery thereof, said disk (505) constituting a regenerative impeller, said regenerative stage further including a stator (504) that defines an annular channel (522) in opposed relationship to said rotor ribs (510), the stator (504) of said regenerative stage including fixed, spaced-apart stator ribs (526) in said annular channel (522).

12. A turbomolecular vacuum pump as defined in claim 11 wherein said rotor ribs (510) and said stator ribs (526) lie in radial planes.

13. A turbomolecular vacuum pump as defined in claim 11 or 12 wherein said rotor ribs (510) and said stator ribs (526) are inclined in opposite directions with respect to the direction of rotation of said rotor (500).

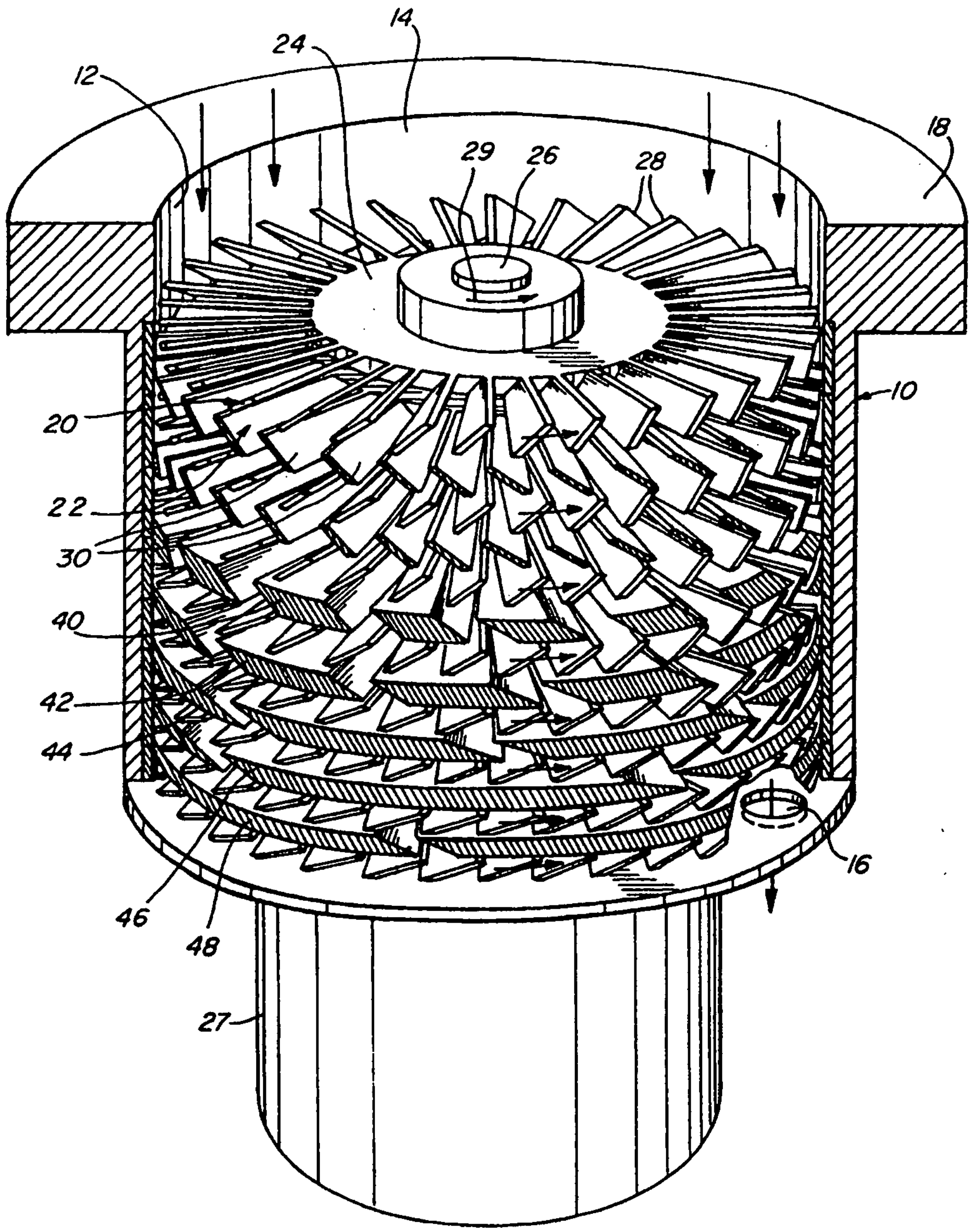


FIG. 1

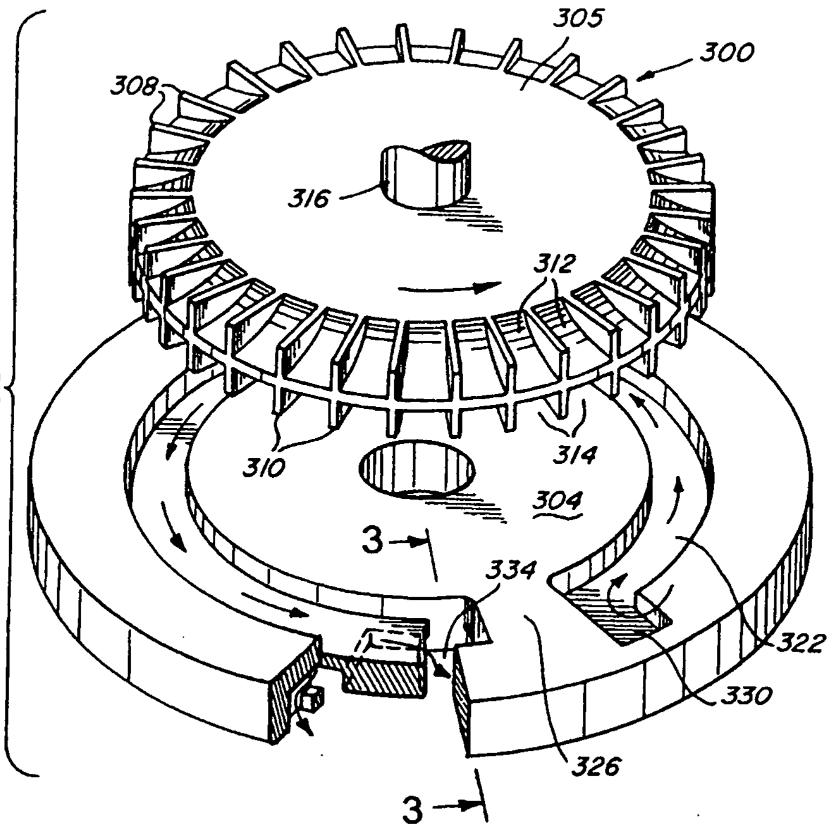


FIG. 2

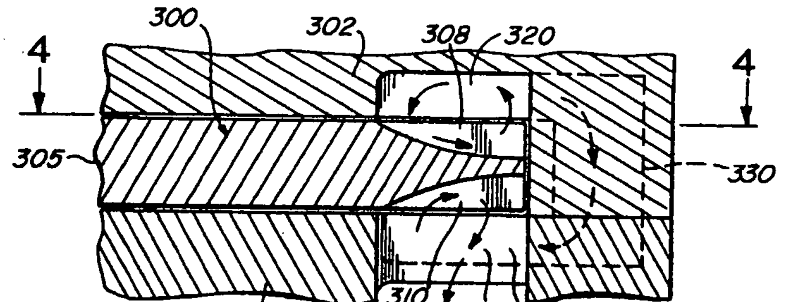


FIG. 3

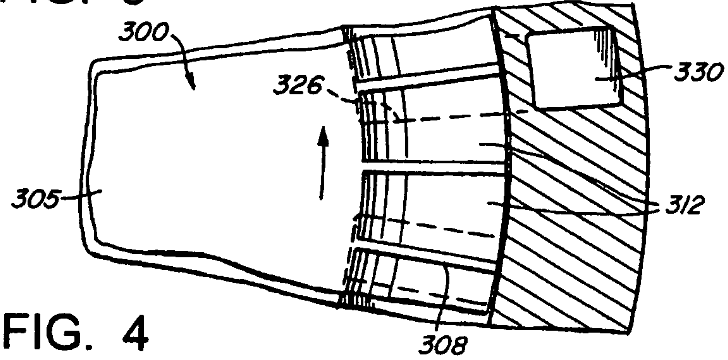


FIG. 4

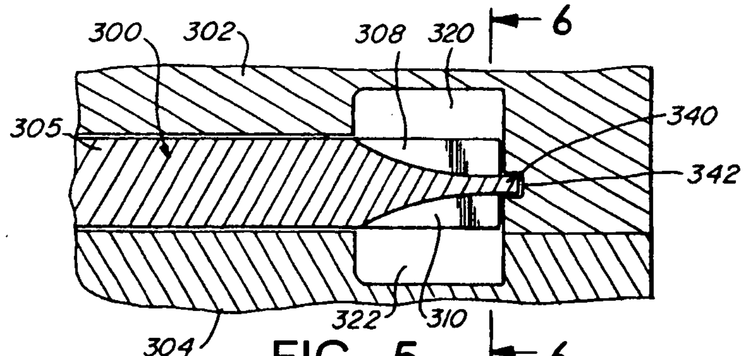


FIG. 5

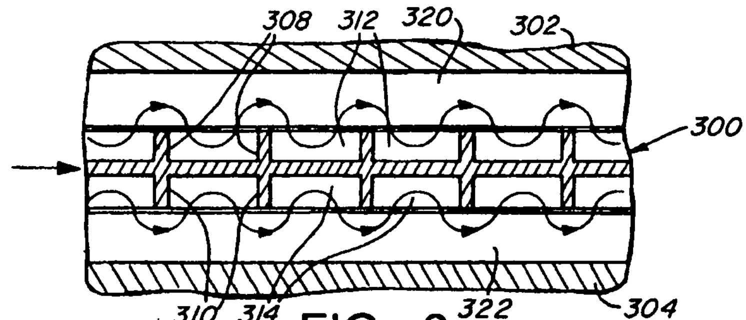


FIG. 6

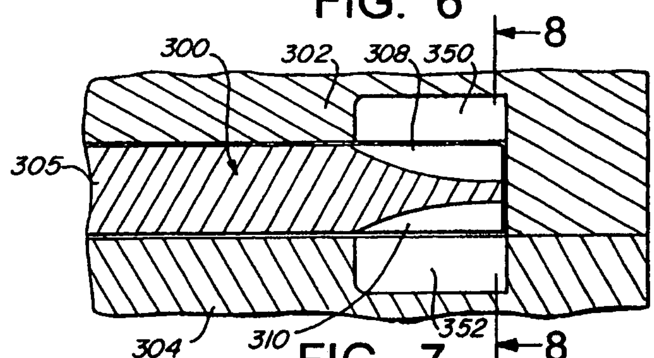


FIG. 7

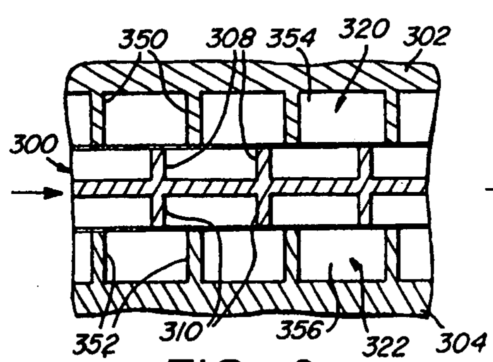


FIG. 8

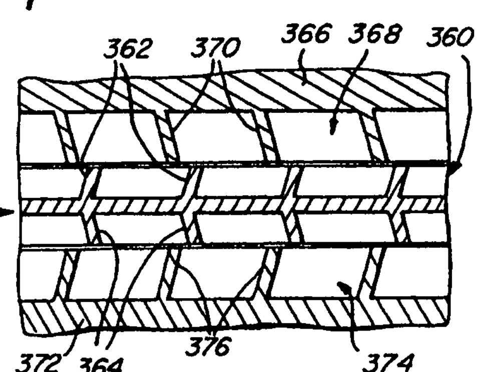


FIG. 9

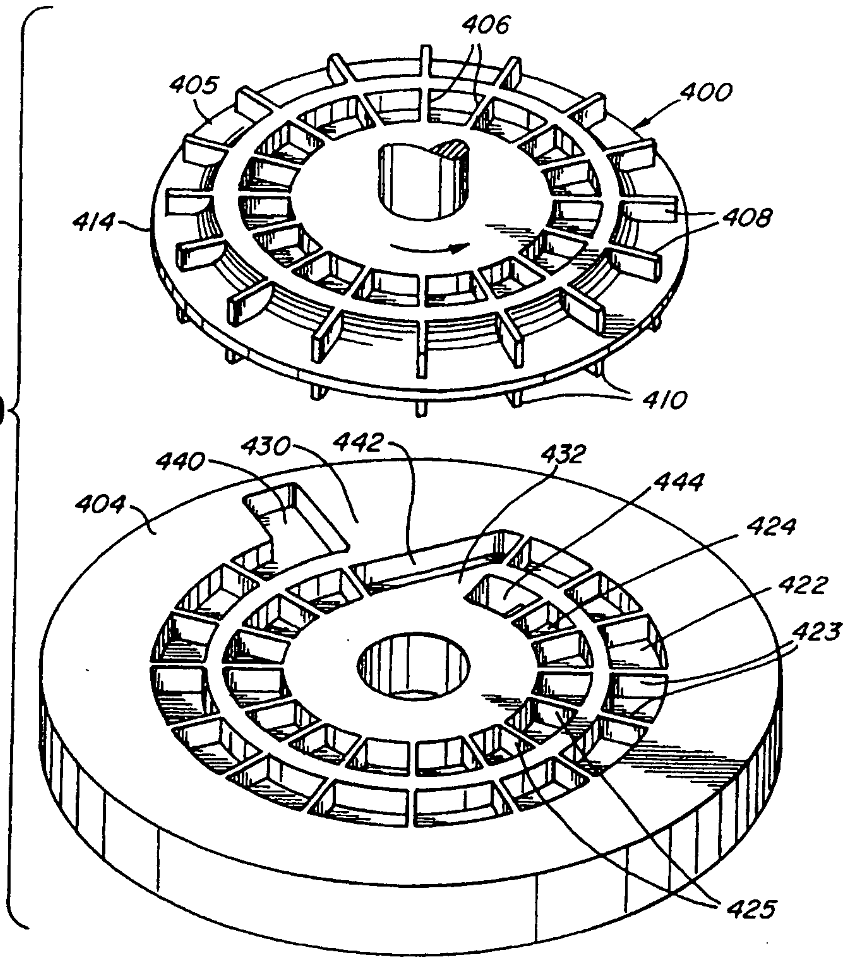

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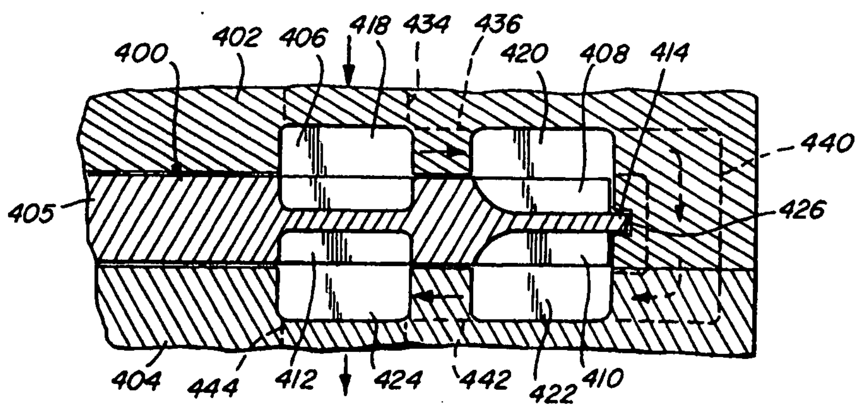
FIG.10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410

FIG.11

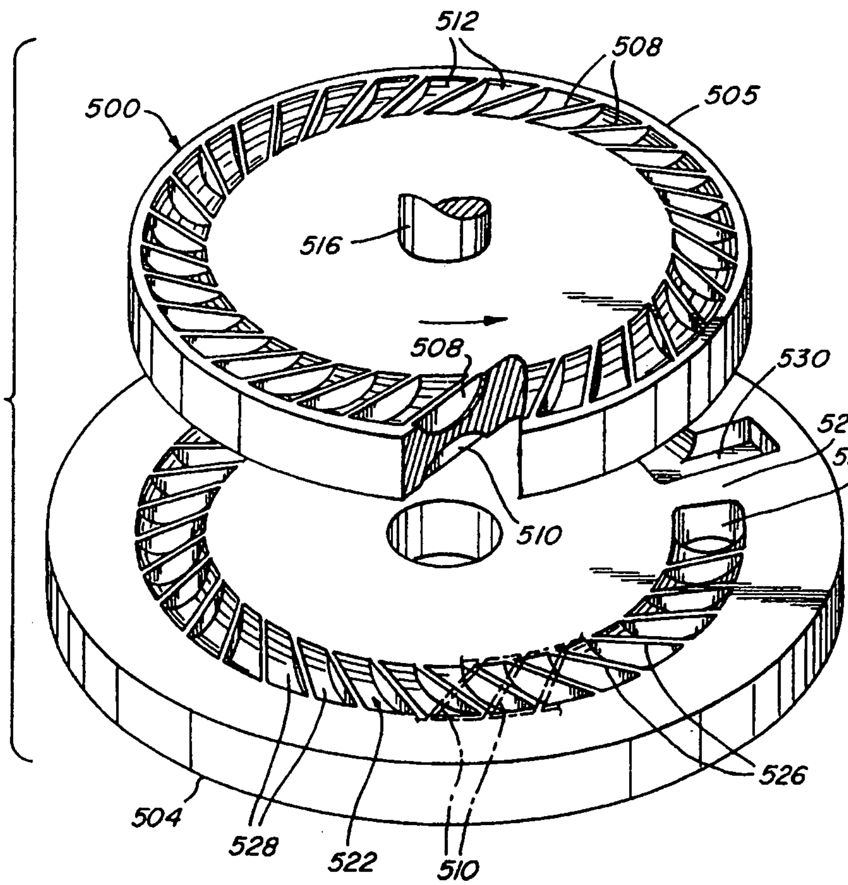

FIG. 12

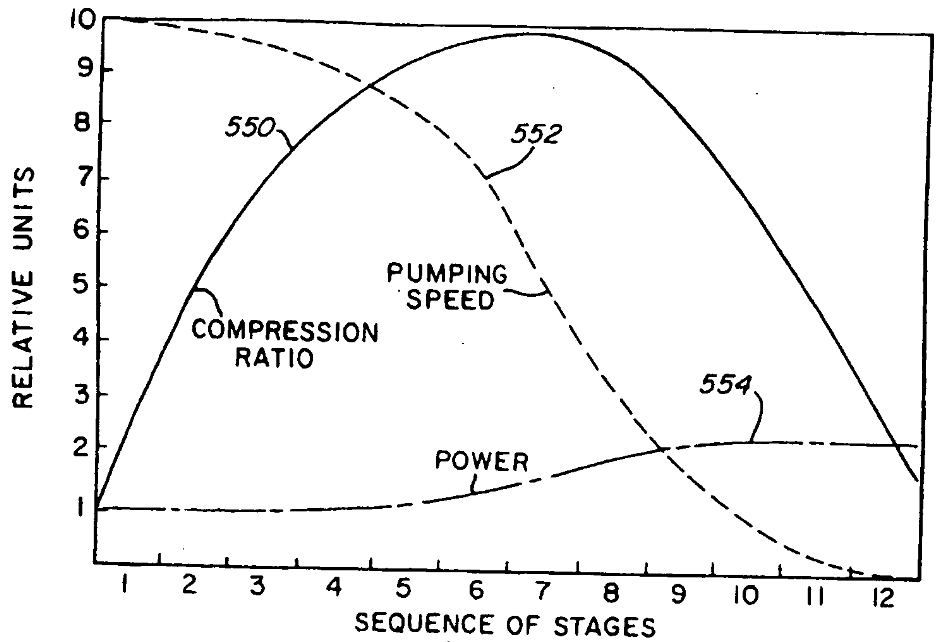
10
9
8
7
6
5
4
3
2
1
RELATIVE UNITS
550
552
PUMPING
SPEED
COMPRESSION
RATIO
554
POWER
1
2
3
4
5
6
7
8
9
10
11
12
SEQUENCE OF STAGES

FIG. 13

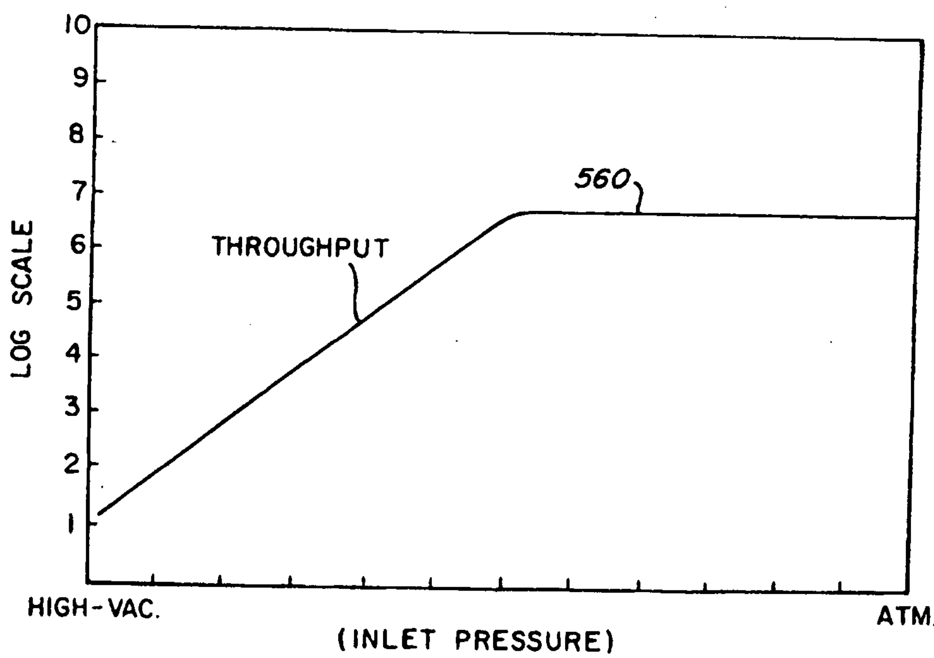
10
9
8
7
6
5
4
3
2
1
LOG SCALE
560
THROUGHPUT
HIGH-VAC.
ATM.
(INLET PRESSURE)

FIG. 14

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 8550

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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A	PATENT ABSTRACTS OF JAPAN vol. 7, no. 63 (M-200) [1208] , 16 March 1983 & JP 57 206795 A (MATSUSHITA DENKI SANGYO), 18 December 1982, * abstract * ---	1,2,8,12,13	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 February 1997	Teerling, J

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